TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE
IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Vol. XIX, No. 2. FEBRUARY, 1942. Price 6d.

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THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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SOIL PROBLEMS IN TROPICAL CROP PRODUCTION.*

It will generally be conceded that one of the most important factors which affects the growth of a crop is the soil in which it is grown. To obtain good yields the soil must be in a state of good fertility, and fertility depends largely on two things: the *presence* of sufficient plant food, and the *absence* of harmful factors. For example, some soils will never give good crops unless they are manured, because they are either naturally lacking in plant food or have been exhausted by previous cropping. Other soils may have ample reserves of plant food but may be waterlogged through lack of drainage, so that plants fail to grow because they have "wet feet". It is the job of the soil scientist to find out how any given soil must be treated so that it will grow and maintain a vigorous crop, and how such treatment can be applied most economically.

It is a popular belief that all land on which virgin forest is growing is tremendously fertile. This is an utter fallacy. To the layman's eye all forest looks more or less alike—dense and luxuriant—and this has been thought to show that the soil on which it grows must be very rich. But those who have to do with the forest know that there are enormous differences in its density and luxuriance—many giant well-grown trees in some areas and only relatively small ones in others. Nevertheless, even on areas of poorer forest, there *is* a density of vegetation much greater than that found on most soils in temperate regions. The fact is that a soil may be quite fertile *under forest conditions*; *i.e.* so long as it is covered with forest, and yet of poor fertility when cleared and planted with another crop. Under forest conditions, with the plentiful rainfall and warmth of the humid tropics, there is a rapid circulation of plant food. Leaves and twigs are constantly being shed: they fall to the ground, are soon rotted down, and their plant foods, nitrogen, phosphate, potash and so on—are released and quickly available for absorption again by the roots of forest plants. This process is many times quicker than it is in a forest in the temperate zone. In this way a given amount of plant food may do duty in the forest much more often than it does in the temperate zone. Copious

* Adapted from an article by H. J. Page published in *The R.R.I. Planters' Bulletin*, No. 16.

leaf-fall results in a permanent layer of leaf mould and humus on the surface of the soil, and the presence of a rich humid zone in the top few inches of the soil itself. The quicker circulation of the plant foods of the soil—root absorption—translocation to the leaves—leaf-fall—rotting—results from the biological and chemical processes which occur in this humus layer, and much of the apparent fertility of the forest soils depends upon it. Thus, under forest conditions, this humus layer is permanent; it is replenished by leaf-fall as quickly as it is rotted or carried away by micro-organisms and insects.

But when the forest is removed from the land this closed forest cycle is broken. The wastage side of the cycle, the rotting away and oxidation of the humus, continues—indeed, it is hastened by exposure to the tropical sun—but the replenishment side of the cycle ceases—there is no more leaf-fall to restore the losses; the humus layer has very soon vanished into thin air—literally so—and the soil is left bare, with only its *innate* fertility at the disposal of the planter. The big differences which may exist in that innate fertility are then revealed. Many soils are now known to be lacking in certain plant foods from the very time they are cleared from forest, *i.e.* the amount of plant food which is supplied under the closed cycle of forest conditions is not enough to allow good vigorous growth of a cultivated crop, unless supplemented by manuring.

The loss of the humus layer which follows the felling and clearing of forest is rapid enough if it depends simply on exposure to the sun and air. But to make matters worse, the usual method of clearing, at any rate until recently, has been to burn off the felled timber and undergrowth. This certainly saves a lot of trouble at the time, but results in immediate erosion of the surface soil, and lays up trouble and expense for the future. In this connection it may be pointed out that in the tropics the surface layer of leaf and humus is generally much shallower than in the temperate zone, the difference often amounting to several inches. The effect of burning will consequently be much more severe on the total amount of humus available in a tropical soil after burning than it would be in the case of a soil in temperate regions since it is the topmost layer of the soil which is mainly damaged by fire. Although opinion is divided on the question of burning, the method clearly offers serious disadvantages, the chief being that by the destruction of surface vegetation and plant seeds the soil is left exposed for a considerable time and the process of soil erosion greatly hastened. In recent years, therefore, methods of clearing without any burning have been developed and are finding increasing favour with progressive planters.

Another serious cause of soil deterioration on clearing from forest is erosion. In the forest the dense cover of undergrowth and humus prevents this from happening even on the steepest land, but after clearing, special measures must be taken if it is to be prevented. Here again the mass of timber on a clearing which has not been burned is a great help. The establishment of ground cover also is no less important as a safeguard against erosion than it is as a means of maintaining a supply of humus. It is always easy to be wise after the event, but it is none the less amazing that until little more than a few years ago clean-weeding was the order of the day on most tropical estates, and this not because a ground cover could not be established but because clean weeding was deliberate.

It will be seen that the aims of soil scientists working in the tropics may therefore be defined as: first, the study of methods of conserving the fertility of the original soil, both in keeping up its content of humus and plant food and in preventing the loss of the soil itself by erosion; second, the study of methods of adding to the original fertility of the soil, where this is too low to allow the best results to be obtained from the crop grown on it; and, finally, the restoration of fertility which has been lost by the treatments and cropping of the soil in the past.

The main problems will include the comparison of *methods of clearing, e.g.* with and without burning; comparison of methods of preventing *soil erosion* by mechanical means such as contour terracing, bunding, silt pitting; the comparison of merits of different kinds of *ground cover*, such as natural covers and introduced leguminous covers, together with a study of the best means of establishing such covers among the young and mature crop; the study of all these various methods in relation to their effects on erosion losses, growth of the crop, and humus content of the soil—the latter also in relation to other methods such as burying green material, mulching, composting, etc.; finally, the study of the *manuring* of crop areas, newly planted, replanted and mature, and the relation of manuring to the other problems.

Underlying all this is the need to study the nature and properties of the soils themselves. In some parts of the world, such as the prairies of North America and the steppes of Southern Russia, there are whole regions where the soil and climate are practically the same for hundreds of miles, so that the same methods of husbandry can be applied with little or no modification everywhere. In many British Colonies this is very far from being the case. We have a wide variety of soils, many of low fertility. A detailed *soil survey* of all crop-growing areas must therefore be carried out, involving study of these soils in the field and their analyses in the laboratory. Along with this there must be a scheme of *experiments in the field*, and each type of experiment must be repeated many times on *each* of the different kinds of soil. Analyses in the laboratory are not enough; so many other factors are involved that reliable conclusions can be reached, and trustworthy advice be given, only when we know how the crop itself responds, and how this response varies from one soil to another, when different carefully chosen methods of treatment are applied under ordinary estate conditions.

GRAPES FOR TROPICAL AMERICA.

BY

WILSON POPENOE.

(*United Fruit Company*)

During the colonization of the Atlantic seaboard of North America by the English, grape growing received serious consideration throughout that region. Vines, and experienced vineyardists to cultivate them, were brought from France. Lack of resistance to cold, insects and disease in the northern area, susceptibility to disease and insect injury in the southern, are now generally considered responsible for the failure which marked these early efforts.

Before the end of the eighteenth century attention turned toward native American species of *Vitis*, by which the colonists were abundantly surrounded. The cultivation of European or *vinifera* grapes eventually moved to more favourable climates west of the Rockies, where it has attained great commercial importance, while a new horticultural race, combining a certain amount of vinifera blood with that of several American species—chiefly *V. labrusca*—was developed in the East.

The Spaniards in the south, like the English in the north, gave early thought to the establishment of grape culture in their new dominions. And with even more reason, for amidst the strange surroundings and stranger fruits of the tropics they longed for the familiar products of their native country. In his fourth letter to the King (1524) Hernando Cortés asked that no ship be allowed to sail for Mexico without bringing plants, "which will be of great service in the development and prosperity of this land."

There can be no doubt that European grapes were introduced into many parts of tropical America during the sixteenth century. At the northern edge of the tropical zone—in Mexico—and at the southern—in Peru, Chile and Argentina—they were successful. In strictly tropical regions, even when planted in relatively dry areas where the climate was least favourable to diseases, results were not so good.

Some of the early chroniclers assert that vines were cultivated successfully, and good wine made from the fruit, in Guatemala, in Honduras, in Nicaragua, in Ecuador and other tropical regions; and they attribute the abandonment of a young and promising industry to prohibitions placed by the King. In order to stimulate an interchange of products with the Mother Country, it was forbidden to produce wine and certain other commodities in the American possessions.

This is probably not the whole story. A century of freedom from these restrictions has failed to bring about the commercial development of grape-growing in the tropical republics, though marked success has attended efforts along the same lines in subtropical areas such as southern Peru, Chile, and Argentina.

The answer is to be sought in climatic conditions. "The vinifera grape," writes Frederic T. Bioletti (1), "is a typical fruit of the semi-arid subtropical regions. It will not thrive in regions of humid summers, whether temperate or tropical, nor in regions of intense winter cold, nor of short or cool summers. Its essential requirements in this respect are a hot dry summer and a cool wet winter . . . . Rains after the grapes begin to ripen are deleterious unless they are light and short. A humid atmosphere during warm weather makes it very difficult to control fungous diseases such as peronospora, black rot, and anthracnose."

Had settlers in the tropical regions of America early adopted the policy followed by the English in the north—had they abandoned attempts to grow vinifera grapes and cast about for other forms of *Vitis* better suited to their climates—it is probable that table grapes and native wines would abound today from Mexico to Peru. In their devotion to the grapes of Europe they failed to develop grapes which, though perhaps not quite the same, would be wholly acceptable as regards table quality and the production of good wines, and which would at the same time grow more satisfactorily in the tropics.

The Present Situation.

With few exceptions, residents of the American tropics continue to limit their viticultural activities to the cultivation of vinifera grapes, and with indifferent or no success. An occasional vine in a sheltered patio, an occasional small planting in the open under particularly favourable climatic conditions and with the skilful care of some horticulturist versed in the technique of pruning: these do exist, and have produced sufficiently satisfactory results to keep alive a general interest in grape culture.

The largest and best of such plantings which has come to my notice during many years of travel in tropical America is one which exists in the town of Valencia, Venezuela. Nevertheless, H. Pittier (2) in writing of Venezuelan plants, says: "The vine, brought probably from the Canaries, is cultivated on a small scale in the hottest and driest parts of the country, such as Cumaná, La Guaira, etc. Numerous people have contemplated the commercial production of wine, but this is a delusion. It can be stated definitely that vinifera grapes do not prosper in the tropics."

(1) Elements of Grape Growing in California. *Circ.* 30, *California Agr. Ext. Service Berkeley*, 1929.

(2) Manual de las Plantas Usuales de Venezuela. Caracas, 1926.

There are a few small plantings in the Cauca valley of Colombia from which grapes are harvested and bring high prices in the local markets. The owner of at least one of these plantings has told me personally, however, that crops are too small and irregular to make such undertakings profitable. In the same country there is a small commercial production of vinifera grapes, mostly from vines grown individually in dooryards, around the town of Rio Frio near Santa Marta. This is an unusually hot and dry region; but even here I have never seen a bunch of grapes well and uniformly ripened. One buys them because they are grapes, not because they are good grapes.

In former days—a quarter of a century ago—there were a few small vineyards in the neighbourhood of Ambato, Ecuador—a famous fruit-growing region. Recently I have noted that these plantings practically have disappeared. The climate of Ambato is probably too cool, since the elevation is above 7,000 feet.

In the same country small vineyards are occasionally to be seen on the slopes of the Guaillabamba and Chota valleys north of Quito. These are dry regions, and the Chota has an elevation of only 5,000 feet which means that the climate is fairly hot. Local tradition is to the effect that the monks cultivated grapes there in Colonial days, and made good wine. But certainly the viticultural industry today is in anything but a flourishing condition.

At sea level on the south coast of Jamaica, not far east of the city of Kingston, there is a region of very little rainfall where vinifera grapes are as successful as at any place I have seen them in the tropics. Here there are a few vines, mostly in dooryards, from which grapes of a fair quality are sold to passers-by.

The list could be continued indefinitely: in hot dry parts of Guatemala and Honduras an occasional vine is seen, as also in Cuba, Costa Rica, and other regions. But the fact remains that vinifera grapes are not wholly satisfactory in any of these, and we must look to other species of *Vitis* if we are to place viticulture in tropical America upon a sound commercial footing.

This movement has already commenced through the introduction of the Isabella grape in several tropical regions. In all probability it will not extend appreciably until other good varieties are available. There is ample material from which these can be developed. Before going further with the subject, let us consider briefly the principal cultivated forms of *Vitis*, since all of them probably will take part.

Cultivated Races.

1. European or vinifera grapes, horticultural varieties of *Vitis vinifera*. This, as the common name indicates is an Old World species, the only one known to horticulture at the time of the discovery and colonization of the New World. It is the classic grape of history and still the favourite everywhere it can be grown successfully. "More than 90 per cent. of the cultivated vines in the world," writes Professor Bioletti, "are pure vinifera." There are hundreds of varieties, which renders difficult the varietal identification of most of those grown in tropical America.

2. American bunch grapes. These are the cultivated grapes of the eastern and central United States, developed from various native species with the infusion of the European grape through natural or controlled hybridization," to use the words of Elmer Snyder (3) who further says: "The species from which the varieties of this group have been derived rank in importance in the following order: *Vitis labrusca*, *V. vinifera*, *V. aestivalis*, *V. linsecomii*, *V. vulpina*, *V. aestivalis* var. *bourquiniana*, *V. champini*, *V. rupestris*, and *V. cinerea*."

This group is represented in the United States by many commercial varieties of which a few of the best-known are Catawba, Concord, Delaware, and Niagara. Those interested in the botany of American grapes cannot do better than consult L. H. Bailey's recent exhaustive study entitled "The species of grapes peculiar to North America", in *Gentes Herbarum*, Vol. III, Fasc. IV published at Ithaca, New York, 1934.

3. Muscadine grapes. These are horticultural forms of *Vitis rotundifolia*, native to the south-eastern portion of the United States. They are quite distinct from other grapes both in growth and in fruit characteristics. The plants are very robust, but the berries, of which few are borne in a cluster, have tough skins and a somewhat musky flavour. Scuppernong is the best-known variety; others are Eden, James, Mish and Thomas. These are generally self-sterile and require the presence of a staminate vine to insure good productiveness.

The Isabella Grape.

With this brief sketch of the botanical background of grape varieties cultivated in America, it is in order to devote attention to Isabella, the first grape to indicate the viticultural possibilities of the American tropics. A. J. Downing, in his classic "Fruits and Fruit Trees of America" (revised by Charles Downing, and published at New York in 1860), says:

"This very popular grape, a native of South Carolina, was brought to the north and introduced to the notice of cultivators about the year 1818 by Mrs. Isabella Gibbs, the wife of George Gibbs, Esq., in honour of whom it was named. Its great vigour, hardiness, and productiveness with the least possible care, have caused it to be most widely disseminated. A vine growing here has borne 12 bushels of grapes in a single

(3) *Cf.* Grape Development and Improvement. Yearbook of the U.S. Department of Agriculture, 1937.

year. It is, perhaps, a little more hardy and ripens earlier than the Catawba, which renders it valuable at the northern part of this state (New York), or the colder portion of New England. No farmer's garden, however small, should be without this and the Catawba."

"Bunches of good size—five to seven inches long—rather loose, shouldered. Berries oval, pretty large. Skin thick, dark purple, covered with a blue bloom. Flesh tender, with some pulp, which nearly dissolves when fully mature; juicy, sweet, and rich, with slight musky aroma."

"This grape is frequently picked as soon as it is well coloured, and long before it is ripe."

Certainly there is nothing in this account to suggest that Isabella would prove adapted to cultivation in the humid tropics. Nor is there in the little which is known regarding its ancestry. L. H. Bailey, discussing the origin of American grapes in his "Standard Cyclopedia of Horticulture", says: "Already a number of popular varieties show such wide departures that they cannot be referred positively to any species. Of these Delaware and Isabella are examples" Elmer Snyder (*loc. cit.*), considers the parentage of Isabella to be *Vitis labrusca* and *V. vinifera*, an opinion held also by another modern authority, Philip Wagner (4) who gives the following interesting account of this variety.

"A blue grape, one of the two varieties which survived Jacques Dufour's Kentucky and Indiana colonies. It makes a poor red wine, but since it is hardy, resistant, and very productive (Dr. Baretto, the Brazilian viticultural expert observed that its fertility is 'simply disgusting') it is grown by poor peasants in France, Italy, Central Europe and many other parts of the world. It makes a much better wine when pressed and fermented white-wine fashion, and is used a good deal by the sparkling-wine makers of the Finger Lakes region, who insist that its white wine rapidly loses its foxiness and grows paler, instead of darker, with age. In some parts of France, Isabella wine is distilled for brandy resembling *slivovitz*, the leading fire-water of Slavic countries. Ripens with Catawba. Generous pruning."

My attention was first called to the tropical possibilities of Isabella by seeing it figured in Gerrit Wilder's "Fruits of the Hawaiian Islands", a work published at Honolulu in 1911. Mr. Wilder refers the variety to *Vitis labrusca* and says:

"This grape was early introduced to these Islands and has become very popular. It is a hardy vine, variable in productiveness, and is practically the only grape grown in any quantity in Hawaii. The leaves are medium size, often roundish and thick; their upper surface is dark green, the under surface is whitish green. The Isabella is an attractive blue-black grape, bearing in large, well-formed, clusters, having a thick bloom. The muskiness of the skin is somewhat objectionable".

A few years later I saw this grape cultivated, in the vicinity of Barbacena, Minas Geraes, Brazil; but it was not until I reached Honduras in 1925 and saw it growing lustily and fruiting abundantly at sea level in the humid climate of the north coast of that Republic, that I was impressed with its extraordinary climatic adaptations. Here is a variety originated in the southern United States, hardy enough to be cultivated in New England, yet at the same time able to withstand the hot humid climate of the tropics.

From sea level Isabella can be cultivated successfully in Central America up to elevations of six or seven thousand feet, but it is not grown extensively in this part of the tropics. In the Cauca valley of Colombia, scarcely more than three degrees from the Equator—but at an elevation of 3,000 feet—it is cultivated commercially. According to Jaime Villegas, professor of agronomy at the Escuela Superior de Agricultura Tropical in Cali, there are perhaps fifty acres now in production, mostly in the form of small vineyards rarely over one acre in extent. The plants are not grafted: they are grown from cuttings. They are trained upon trellises with horizontal wires at a height of five or six feet above the ground. Two crops are produced each year. It is customary to wait about one month after a crop has been harvested, then prune severely—and this is invariably done when the moon is waning.

Professor Villegas further says that vines will remain in good production at least 10 to 15 years—20 to 30 crops. There being no well-marked seasons in the Cauca valley, pruning can be done without regard to month, and a crop will ripen 100 to 120 days later. Commercial production commences the fourth year after planting, though a few bunches will be produced by most vines from the second year onward. The soils of this region—at least those of areas where grapes have done best—are gravelly clays and gravelly loams running down to gravel. Stable manure and wood ashes are occasionally used to assist backward plants.

Mildew does not seriously attack Isabella grapes in the Cauca valley, but with vinifera varieties it is troublesome. Two or three insect pests have been noted, but they have not assumed importance as yet.

Another account from the same part of tropical America is contained in an interesting little book entitled "El Cultivo de la Vid en Colombia", published at Bogotá in 1938. Its author, Edmundo G. Corradine, deserves credit for having brought together much information regarding the cultivation of vinifera grapes in the vicinity of Bogotá; and above all, for predicting that the future of

(4) Wine Grapes. New York, 1937.

grape growing in tropical America depends upon the production of hybrids between *vinifera* and such tropical species as *V. tiliaefolia*. Says Señor Corradine (I translate): "Isabella has given me good results here in high, cool climates; the fruit is resistant to Oidium and the leaves to Peronospora, though they are not immune. In rainy weather when it is difficult to defend Muscatel grapes against the attacks of these pests, Isabella remains healthy and takes advantage of the rains to grow vigorously. The grapes are large, attractive and of uniform size, though the bunches are rather small."

Other American Grapes in the Tropics.

The success which has attended the cultivation of Isabella in the Cauca valley and other parts of tropical America raises the question: What about other varieties of North American origin? Isabella is not a grape of wholly satisfactory table quality, especially to those accustomed to the sweetness and lack of "muskiness" which characterise the viniferas. Its value lies in the fact that it is fairly good, and at the same time highly resistant to disease, vigorous in growth, and a most abundant producer if regularly and properly pruned. Among the large number of grape varieties now available in the eastern and southern United States, are there others equally vigorous, equally resistant to disease, and of better quality?

Attempting to answer this question we introduced into Guatemala some ten years ago a representative collection of American varieties including some of the Munson hybrids. T. V. Munson (1843-1915) devoted many years to grape breeding at Denison, Texas—a region rich in native species of *Vitis*, some of them valuable for breeding purposes. Again to quote Elmer Snyder (*loc. cit*), "His work was largely instrumental in producing grape varieties of the bunch type suitable for southern conditions, where most of our varieties of northern parentage fail. Of particular interest and special value was his use of the native species *Vitis linsecomii*, the pinewoods grape, in the origination of hybrids varieties. By combining and selecting the vigorous, healthy native species Munson was able to originate fruiting varieties that are productive, vigorous and better in fruiting qualities than the parental types. More hybrid grape varieties have been originated and introduced through his efforts than by any other agency in the United States."

To date, none of the Munson hybrids has shown in Guatemala either the vigour or the productiveness of Isabella. However, our tests have been limited to a few varieties and a few locations. In passing, it should be noted that an extensive collection of these hybrids has recently been obtained for trial in the Republic of Colombia through the efforts of Ing. Rafael R. Camacho of the Ministerio de la Economia Nacional.

Several varieties of the Muscadine group—Scuppernong, Thomas, and Mish—have been planted in Guatemala without very conclusive results to date, because staminate pollenizers were not brought with them. Their growth has been fairly healthy, but not as vigorous as in the United States.

It remains to mention one other variety, probably Niagara, which has turned out so well that it has been propagated and distributed. This variety (of which the label was unfortunately lost) is not very robust, but has shown admirable resistance to disease. The bunches are of good size, as are the whitish green berries, and the quality is definitely superior to that of Isabella. Three years ago I sent cuttings of this variety to the Cauca valley in Colombia, where Jaime Villegas reports that two-year-old plants have produced a few bunches of excellent fruit. Niagara originated in New York state about 1872; it is believed to be of mixed *labrusca* and *vinifera* parentage. There is an excellent coloured illustration of this grape in Professor Bailey's "Standard Cyclopaedia of Horticulture."

The Future of Grape Culture in the American Tropics.

Four hundred years of unsatisfactory experience with *Vitis vinifera* in warm humid regions should convince us that the future of commercial grape culture in tropical America depends upon the development of varieties better adapted to local conditions than are any of this species. Experience with Isabella, it seems to me, points to the proper line of attack.

Further evidence—and very weighty evidence—is to be found in the recent breeding work of Joseph L. Fennell at Princeton, Florida. Princeton lies some 25 miles south of Miami, in that part of Florida where climatic conditions most closely approach those of the tropics. Northern grapes do not thrive in this region. It was this fact, together with the presence of numerous interesting wild grapes, which suggested to Mr. Fennell the desirability of breeding work. Its progress has been set forth recently in a brief paper entitled "Future 'Ideal' Grapes" published in the *Journal of Heredity*, June 1941. In addition, he has sent me in manuscript form a paper which he read before the annual convention of the Florida Grape Growers' Association at Eustis on July 17, 1941; also some highly interesting manuscript notes which are summarised below.

"Early in this work" said Mr. Fennell in his talk before the Florida Grape Growers, "I became convinced that if viticulture was to succeed in south Florida and the hot humid parts of the world, it must be based on tropical or subtropical native stock. Thereupon an effort was commenced to comb the woods and swamps of southern Florida and the American tropics for the best wild grapes. Charts were made on which were indicated the natural ranges of the more valuable species. Where certain of these overlapped, a search was made to find natural hybrids."

"The conclusion ultimately reached was this: That of all the vast tropical and subtropical humid regions of the earth the best grape resources are right here in Florida, supplemented for good measure by those of southern Mexico and the West Indies. The wild grapes which in my opinion have the most value as a basis for hot-humid climate viticulture are the better forms and hybrids of the redshank grape (*Vitis rufotomentosa*); the south Florida fox grape (*V. shuttleworthii*); the Florida blue grape (*V. gigas*); the uva cimarrona, uva silvestre or agraz of tropical America (*V. tiliaefolia*); and the totoloche of southern Mexico (*V. popenoei*). The best forms of the south Florida muscadine (*V. munsoniana*) and the figleaf grape (*V. smalliana*) are also of considerable merit. Most of these species have individual and often serious faults in themselves, but within the group are nearly all of the characters needed to build a fine race of warm-climate vineyard grapes."

"Since the beginning of this work I have made an effort to incorporate in my hybrids as much European or *vinifera* blood as seemed feasible under Florida conditions. Much attention has been paid to the determination of those vinifera varieties which combine in the best all-around manner with the wild or native parent. Of the European varieties tested some fifteen have been used in breeding experiments with wild tropical and subtropical selections."

"From results of the work up to this point the one noteworthy indication is this: it is *vinifera*, even more than the American sorts, which holds the key to Florida viticulture of the future."

Breeding Material.

In other words, Mr. Fennell has arrived at the same conclusion which was reached in early days by grape growers in the north, namely, that we need vinifera blood in our hybrids for good table quality, but we need native American blood for disease resistance.

The technique of grape breeding, and the present status of breeding work in the United States and several other countries, are described by Elmer Snyder (*loc. cit.*). Nothing is said, however, regarding the development of superior grapes for the tropics. So far as I have been able to learn, Mr. Fennell is at present the only one working seriously on this problem. Below are notes which I have expanded somewhat from a manuscript table he has kindly sent me with permission to use in this article. This table was entitled "known *Vitis* species of greatest promise for the development of hot-humid climate viticulture."

Before setting forth these notes I would like to quote one paragraph from Mr. Fennell's recent paper in the *Journal of Heredity*, cited above:

"Since we have ample proof that high quality is easily obtainable in European × American grape hybrids through careful selection of parents, our one important problem is to produce this superior fruit on disease-free vines. Before this can be done we must know what are the more important weaknesses and maladies and how they can best be overcome. The most destructive pests toward which our so-called "Ideal" grapes must show a high resistance are as follows: root louse (*Phylloxera vastatrix*); downy mildew (*Plasmopara viticola*); black rot (*Guignardia bidwellii*); anthracnose (*Sphaceloma ampelinum*); ripe rot (*Glomerella cingulata*); and several leaf-spot fungi."

Species.

Vitis shuttleworthii, the Florida fox grape. Mr. Fennell points out that the berries of this species are harshly acid, but sometimes larger than those of nearly all other wild grapes. For breeding purposes, he considers *V. shuttleworthii* useful because of its vigour and productivity, as well as size of berry, thinness of skin, juiciness, and small size of seeds. Its undesirable characteristics are susceptibility to downy mildew, small size of fruit cluster, toughness of pulp, and pungent acidity.

Vitis rufotomentosa, the redshank grape of Florida. Valuable for its resistance to disease, its vigorous growth, its large fruit cluster, and the flavour and sweetness of its pulp. Against it are the too compact nature of the bunch and the small, rather seedy berries.

Vitis popenoei, the totoloche of southern Mexico. This is a species recently described by Mr. Fennell (5) from plants of Mexican origin cultivated in southern Florida. In discussing it at the time he published the botanical description he said: "In addition to its botanical differences, *V. popenoei* occupies a distinct climate and a range several hundred miles farther south than that occupied by either of the other two known species of *Muscadinia*. It is the first and only muscadine grape yet known to occur naturally within the tropics." The native home of this species is in the Isthmus of Tehuantepec, where fruits from wild plants are collected and brought into the local markets for sale. Mr. Fennell considers this species of unusual value for breeding purposes because of its vigour and disease resistance as demonstrated in his Florida vineyard; because of its muscadine relationship and the facility with which it can be hybridised with species of the Euvitis or bunch-grape section; and because of its large berries of relatively good table quality. Its only unfavourable characteristic is its susceptibility to cold — which is, of course, unimportant when development of grapes for tropical climate is the objective.

Vitis tiliaefolia (syn. *V. caribaea*), the Caribbean grape; uva cimarrona, uva silvestre, and agraz of Spanish-speaking countries. Widely distributed throughout tropical America. This disease-resistant, vigorous wild species was called to the attention of plant breeders as early as 1915 by Earle and Popenoe (*cf.* Plant Breeding in

(5) *Cf.* Two new North American species of *Vitis*, *Journal of the Washington Academy of Sciences*, Vol. 30, No. 1, January 15, 1940.

Cuba, *Journal of Heredity*, Vol. VI, No. 12, Washington, D.C., 1915) who recommended its use in the development of good table grapes for the tropics. Mr. Fennell has illustrated in his recent paper published in the *Journal of Heredity* one of his productions which he calls the Fairchild grape. He says of it: "This novel hybrid shows the improvement possible through using the more healthy small-fruited American species. It is an F_1 hybrid of the Central American uva cimarrona and the European variety Alphonse Lavallee. Though neither sprayed nor dusted it has been vigorous and healthy in a region where grape pests are usually devastating. It is the first improved grape on record to be derived from a tropical wild species." In his tabulation of breeding material, Mr. Fennell lists as the good qualities of *V. tiliaefolia* its vigour and disease resistance while the small size and acidity of the berry are against it. Having seen this plant thriving in tropical America under widely diverse conditions of climate and soil, it is my own opinion that it is likely to prove extremely valuable in the development of better tropical grapes.

Vitis gigas, the Florida blue grape, recently discovered and described by Mr. Fennell, who considers it valuable for its vigour and productivity; its large compound fruit cluster; and the good quality of its medium-sized fruit. It is slightly subject to downy mildew.

Vitis munsoniana, the bird grape of southern Florida, which L. H. Bailey describes (*cf.* Hortus 1930) as a "muscadine grape, differing from *V. rotundifolia* in being a more slender grower continuously flowering or fruiting, the leaves less pointed, the fruit smaller with thinner skin and tender pulp lacking the strong flavour." In speaking of it, Mr. Fennell says: "One selection of *V. munsoniana* which was found in the woods of southern Florida produces berries as large as those of Carman or Ives. The pulp is of a meaty though not tough texture, very similar to that of most vinifera grapes. This is the only truly American grape known to me which has this characteristic." It has considerable value for breeding purposes because of its muscadine relationship, its vigorous growth, and its medium sized berries of good quality. Its objectionable characteristics are the small size of the fruit clusters and the difficulty with which it hybridises with species of the Euvitis section.

Vitis smalliana (syn. *V. simpsoni*), the figleaf grape of south Florida. Considered valuable for breeding because of its disease resistance and its medium-sized clusters of pleasantly-flavoured berries. Against it are the thick skin of the latter, and the large seeds.

In Conclusion

I cannot do better than reproduce a recent note from Mr. Fennell, who is working, it should be remembered, in a region which to all intents and purposes — so far as plants are concerned — is a corner of the West Indies. He writes:

"A few of my F_1 crosses between the wild Florida kinds and Munson's Extra (Florida Beacon) have the Florida Beacon or Concord flavour fully 95 per cent. The fruit of the hybrid is, I believe, superior to either Beacon or Concord since the flavour is somewhat sweeter and the pulp about the seeds not so tough. The berries of this cross average about $\frac{3}{8}$ inch in diameter. The productivity of the vine is not yet fully demonstrated."

"No vinifera variety yet tried in Florida has been successful and few varieties survive the first summer; yet several F_1 hybrids of certain vinifera sorts with wild Florida selections seem to be perfectly at home. None of the northern American cultivated sorts shows any promise whatsoever in southern Florida. I have imported Isabella from Hawaii and I have tested nearly all the better-known northern labrusca varieties and hybrids. None does well here."

INDEX TO HORTICULTURAL ABSTRACTS.

Imperial Bureau of Horticulture and Plantation Crops. Index to Horticultural Abstracts Volumes I-X, 1931-1940. I.B.H.P.C., East Malling, Kent, England, 1941, pp. 160, 25s.

At the first Imperial Horticultural Conference held in London in August, 1930 the following resolution was adopted "That a commentary on current horticultural literature is desirable and should take the form of summaries of sufficient length to indicate the contents and scope of the papers concerned."

Horticultural Abstracts was the result and ever since this quarterly journal has faithfully recorded in the form of comprehensive abstracts in English the gist of the more important papers on horticultural research wherever and in whatever language they may have appeared.

To ensure efficient service the continuous examination of a vast assortment of scientific periodicals has been necessary, for the subjects classed as horticultural are many and wander from the beaten track of straightforward cultivation of commercial fruits and vegetables far into tortuous scientific by-paths in which none but an expert guide can find the way.

Now, after 10 years in which *Horticultural Abstracts* with its yearly index has provided the necessary guidance the work has been rounded off by a provision of a single, comprehensive, subject and author index covering the whole period. In it the subject matter of more than 9,500 papers is carefully cross-referenced; how wide their compass a mere glance at the index will reveal.

The inquisitive horticulturist using both index and abstracts in conjunction will here find an efficient summary of information on all modern horticultural problems, together with exact references to original work.

SOIL EROSION IN TRINIDAD AND TOBAGO.

By F. Hardy.
(*Imperial College of Tropical Agriculture, Trinidad, B.W.I.*)

(A) TRINIDAD.

(1) Northern Range.

This region comprises (*a*) a west to east "backbone", (*b*) high mountain ridges up to about 3,000 feet altitude running at right-angles to this, and separated by deep south-trending valleys, (*c*) steep, rugged north-coastal slopes, and (*f*) a foothill belt forming the southern part of the range having elevation up to 500 feet. Whereas the highest mountain masses are still under virgin rain forest, the foothills have suffered considerable deforestation and agricultural exploitation by peasants, and both sheet and gully erosion on a severe scale have taken place, particularly in the western part of the belt. Soil erosion in this area has recently been described by J. C. Cater, Assistant Conservator of Forests.* The soil is very shallow, with the parent quartz-schist rock lying within 6 inches of the surface, and large quartzitic boulders strewn over the land. It is incapable of supporting more than two or three successive crops of corn, and its deterioration is greatly accelerated by the customary periodic burning which forms a necessary operation in the pernicious practice of shifting cultivation on these steep slopes.

The land between crops goes back to second-growth bush, chiefly comprising Cocorite Palm (*Maximiliana regia*), Gru-Gru Palm (*Acrocomia*) and Trash Palm (*Scheelea*) with Bloodwood (*Croton*), Balsa (*Ochroma*), Kiskidee (*Vismia*), etc., but eventually, if burnt sufficiently frequently, it may entirely fail to regenerate an arboraceous vegetation, and grassy and scrubby "natural savannas" may result. Such is probably the origin of the conspicuous bare area occurring on the broad hill-spur above St. Joseph, though in this case the "savanna" may have been created originally by Caribs.

Along the steeper valley-sides within the range proper, *débris-avalanches* frequently occur during violent rainstorms or cloud-bursts. The deep scars left by them may temporarily obliterate the roads, and the removal of soil may cause devastation to forests and damage to cacao plantations in the valleys.

(2) Northern Plain.

(*a*) *Caroni Plain*: This flat area, situated on the west of the plain, is mainly utilised for sugar-cane cultivation, and a large part of it has been continuously cropped for many years. It contains six large sugar factories, each supplied from estate fields and peasants' holdings lying within this area. Its swamp and alluvial soils have suffered *sheet-erosion* in the highly-cambered cane-beds, and their profiles have been somewhat truncated and much disturbed and mixed through deep tillage by tractor-drawn implements.

(*b*) *Sangre Grande Basin*: This area is utilised for growing cacao. Its rainfall is much higher than that of the last area (*i.e.* over 100 ins., as against 65 ins.). Its alluvial clay soils have likewise suffered considerable *sheet-erosion*, judging by their low contents of organic matter having low C/N ratios in the surface soils. The area is subject to flooding during the wet season, when water may cover the cacao fields to considerable depth. As this water sweeps away, it lifts and carries with it much loosened humic surface soil and leaf litter into the main east-flowing rivers and thence to the sea.

(*c*) *Manzanilla District*: This is an undulating area bordering the last on the south and south-east. It comprises mainly well-structured soils derived from calcareous clays and utilised for cacao-growing. Some *sheet-erosion* may have occurred on the hillslopes, but the prevailing soil-types here would not be regarded as particularly erodible.

(*d*) *Las Lomas District*: This area occupies the middle and south of the Northern Plain. It is characteristically undulating, the little hills chiefly consisting of very erodible loose sandy soil, and the slopes and hollows comprising red clay soil and alluvial soils generally utilised for rice-growing by peasants. The sandy outcrops are partly occupied by forest reserves or by old second growths which protect the soil against excessive erosion.

(*e*) *Swamp Savannas and Swamp Forests*: These are contiguous with the last area along its northern boundary, and lie south of the Northern Range foothills. The soils chiefly comprise Ground-Water Podsol, tending to Ground-Water Laterite where ferruginous hard-pan occurs. The area is mostly under natural vegetation, either Evergreen Rain Forest, Swamp Forest or Herbaceous Grass-Sedge-Palm associations. The soils are mostly useless for agriculture. When clear-felled, drained and periodically burnt, however, the humic, loose, sandy surface soil suffers severe *sheet-erosion* through exposure, so that ultimately it degenerates into waste-land.

Note:—The fact that the more-or-less flat lands of the Northern Plain of Trinidad are undergoing persistent sheet-erosion is specially noticeable during flooding rains, when the water courses of the two main river systems (Caroni and Oropuche) are heavily charged with suspended mud. The estuaries of these rivers, situated respectively on the west and on the east coasts, are gradually silting up. Samples of

* Deforestation and Soil Erosion in the Foothills of the Northern Range caused by Shifting Cultivation, J. C. Cater, *Tropical Agriculture*, Vol. XVI, 1939, pp. 230-232.

mud recently taken at the mouth of the Caroni River, in Port-of-Spain harbour, showed on chemical analysis contents of organic matter ranging from 1.2 to 2.8 per cent. and of nitrogen 0.08 to 0.14 per cent., implying that much valuable soil is being removed from the northern lands.

(3) Central Range.

This consists of a series of W.S.W. to E.N.E. branching ridges embracing several limestone hill-masses of altitude up to 1,000 feet. It is mostly under reserved forest and cacao plantations (Montserrat District). The cultivated soils chiefly comprise good-structured clays derived from calcareous sediments.

Sheet erosion affects the steeper slopes of the poorer grades of clay-soil, but the most conspicuous manifestations of earth movement* are *land-creep* (including soil-creep, earth-flow and occasional débris-avalanche), as well as *land-slip* (including slump and débris-slide). The first are slow flowing movements (except débris-avalanche which is rapid); the second are slow sliding movements, involving the development of slip-planes. The actual rate of movement depends on the angle of slope and on frictional forces to which the moving materials are subjected. Friction is naturally greatly diminished during periods of heavy continuous rain, such as may occur in the wet season, when the soil material becomes thoroughly saturated with water. Geologists claim that the occurrence of gypsum which characterises the subsoil of many of the Central Range clays aids land-slip by enhancing their lubrication. Instances are known in the Central Range cacao area of parts of fields moving downhill, piling the cacao trees into valleys or roads. The gypseous raw sub-soil thus exposed is useless for cacao-growing; it is generally planted in fodder grasses, bamboo or some tree crop such as Teak. Many years must elapse before a productive soil is regenerated from such material.†

While by no means frequent, several catastrophic débris-avalanches or land-slides have occurred, though usually only on a small scale, in the Central Range area during wet seasons. On the other hand, the extent of the much less spectacular, slow, land-creep movements has not been assessed, but doubtless they are perceptible, even in the forest, though requiring careful observation for their detection. The southern flanks of the Central Range hills are steeply scarped, and show the results of geological erosion in great land-slip scars marking the places where clay strata have slipped away and have exposed the limestone as conspicuous cliffs within the Guaracara District.

* *See*: "Land-slides and Related Phenomena", by C. P. Stewart Sharpe, 1938, Columbia Univ. Press, New York, which provided the subject matter of an article by the present writer in *Tropical Agriculture*, Vol. XVII, 1940, pp. 187-192.

† *See*: Cacao Soils of Trinidad (A) Montserrat District (Part (VII) of Studies in West Indian Soils); J. A. McDonald, F. Hardy and G. Rodrigues, I.C.T.A., 1933.

(4) Southern Plain.

This comprises an undulating peneplain of maximum elevation 200 feet, consisting of clay strata (Naparima District), with a large flat alluvial plain (Nariva Swamp) lying to the east of it and abutting onto the east coast, south of the Manzanilla District.

(*a*) *Naparima District*: This area includes in the west the sugar-cane estates of the Ste. Madeleine Sugar Company,* covering some 24,000 acres of land, and in the east around Rio Claro several large cacao estates and peasants' holdings.† The soils chiefly comprise two contrasted clay types running in strips, E.N.E. to W.S.W., right across the area, namely, a typical black Rendzina, derived from foraminiferal marlstone, and a pale-red, highly-acidic clay soil, derived from non-calcareous siltstone. Both show variable *surface erosion* within the sugar-cane area, probably enhanced in recent years by continuous deep cultivation and disc-ploughing with heavy tractor-drawn implements which turn the furrow slices downhill. This has exposed the white marly parent material along the hill-crests and has caused the accumulation of thick deposits of fertile black soil in the hollows. Similarly, it has exposed the red-weathering parent soil material in the non-calcareous siltstone belts.

The red clay soil, whose structure easily breaks down during beating rain-storms, is particularly prone to water-logging in the wet season, and develops small *land-slides*, or slowly creeps down hill, sometimes blocking the roads. One significant result of this insidious soil erosion within the sugar-cane lands of South Trinidad is the gradual loss of nitrogen-containing soil organic matter, which has led to the present wholesale use of artificial nitrogenous manures as an established practice in sugar-cane cultivation.

Within the clay lands of the cacao estates occupying the eastern part of the area, soil erosion is not so obvious, although profile studies conducted there have indicated a certain amount of surface-soil removal in the cacao fields. The name "Rio Claro" suggests that formerly the rivers of this district were devoid of sediment, but this is far from being the case at the present time.

Note:—The gradual loss of surface soil by sheet erosion within the Southern Plain clay-lands originally occupied by forest is well illustrated by the laboratory data we have accumulated for soil profiles examined in various parts of this area, as well as in other regions

* *See* Soils of Trinidad Sugar Estates; C. F. Charter, Trinidad, 1939; Sugar-Cane Investigation Committee.

† *See* Cacao Soil Surveys: Rio Claro District; F. Hardy, J. A. McDonald and G. Rodrigues. *Fourth Annual Report on Cacao Research*, I.C.T.A., 1935, pp. 51-53.

Photo by *J. C. Cater*

FIG. 1

Photo by *J. C. Cater*

FIG. 2

Photo by *J. C. Cater*

FIG. 3

FIGS. 1 to 3—Peasants' cultivations; Red Schist soil, steep slopes cleared for shifting cultivation.
FIG. 1—Maraval district, Figs. 2 & 3 Maracas district.

(*All photographs reproduced by courtesy of J. C. Cater, Esq.*)

SOIL EROSION IN TOBAGO

CASTARA DISTRICT

FIG. 4

FIG. 5

FIGS. 4 & 5—Peasants' cultivations; Red Schist soil, contour banking.

CASTARA DISTRICT

FIG. 6—Peasants' cultivations; Red Schist soil, contour banking.

FIG. 7—Peasant's cultivation; burying crop residues.

SOIL EROSION IN TOBAGO

MASON HALL DISTRICT

FIG. 8
Peasants' cultivations; Brown Igneous Rock Soil.

of Trinidad. The results given in the table below show how far *profile truncation* has proceeded as a consequence of the conversion of forest to cacao cultivations or to sugar-cane cultivations. The progressive diminution in organic matter and nitrogen contents and in carbon-nitrogen ratio is particularly noticeable, and the exposure at the surface of the cacao and sugar-cane lands of humus-deficient highly-acidic subsoil, lacking available phosphate, may thus be partly explained as concomitant on soil erosion.

Computations from these data indicate that the cacao soil profiles have lost, on the average, besides most of the original forest litter, almost 1½ inches of surface soil, while the sugar-cane profiles have lost on the average, more than 2½ inches of soil.

(*b*) The *Nariva Swamp*, which has not yet been reclaimed for agriculture, lies practically at sea level; it receives the drainage from a series of small east-flowing rivers coming off the flanks of the Central Range. Erosion of this hilly country is indicated by the fact that the landward margin of the swamp comprises fresh alluvial deposits showing high productivity when brought into cacao cultivation, the soil here being one of the most fertile in Trinidad.

(5) Southern Range.

This consists of a broad belt of low sandstone hills of elevation between 200 and 500 feet, rarely more, bordering the southern coast. In the east, the range merges with a large expanse of undulating forested country (Guayaguayare District) dissected out of horizontal soft sandstone strata whose remnants form numerous small plateaux. The sandstone erodes readily when the forest is removed, and deterioration from this cause is probably affecting cacao estates that have been established around Moruga on hilly sandy soil.* Similar undulating sandy land occurs adjoining the western end of the Southern Range in the Siparia-Penal District where cacao soils are also deteriorating somewhat, probably partly as a result of erosion.

Linking the coastal hilly sandy lands with the Naparima Clay Belt, is a broad undulating strip of country consisting of non-calcareous silty-clays and marly-silts, much of which is still under forest. Overlying it on the west is the great flat of the Oropuche Lagoon with the intricate ramifications of the alluvial deposits of the Oropuche river system. These present a range of soils, sandy in the east and clayey in the west within the lagoon, derived by erosion mainly from the low hills, comprising highly fertile lands given over to peasant cultivations of rice and ground provisions.

(6) Cedros Peninsula.

This "toe" of Trinidad is really a westerly continuation of the last topographical division, and the land is still mostly under forest. It provides an example of marine coastal erosion having some agricultural importance in that on-shore sea-currents are continuously removing strips of coconut cultivations in some places and piling up corresponding masses of sandy materials in others.

* *See* Cacao and Forest Soils of Trinidad (B) South-Central District (Part (X) of Studies in West Indian Soils); F. Hardy, D. W. Duthie and G. Rodrigues. I.C.T.A., 1936.

Naparima Red Clay Soil.

Depth (ins.)	Index of texture.	Reaction (pH.)	Total O.M. content %	Total N content %	C/N Ratio	Avail. P_2O_5 (p.p.m.)
(A) *Forest* (6 profiles)						
0- 3	47	6.2	7.0 †	0.41	9.9	41
3- 6	45	5.8	2.5	0.21	7.0	21
6-12	44	5.0	1.3	0.14	5.5	14
(B) *Cacao* (7 profiles)						
0- 3	44	5.5	4.8	0.33	8.4	16
3- 6	39	5.2	2.0	0.18	6.5	14
6-12	37	5.1	1.1	0.11	5.6	7
(C) *Sugar Cane* (8 profiles)						
0- 3	38	5.5	2.5	0.17	8.4	20
3- 6	39	5.4	2.1	0.16	7.4	14
6-12	43	5.0	1.4	0.12	6.6	8

† Litter removed.

(B) TOBAGO.

Chief Features:—This Ward of the Colony lies 26 miles N.E. of Trinidad. Its dimensions are 26 by 7½ miles. It consists of a central ridge of high land, 10 miles long, with greatest elevation 1,850 feet, which slopes rapidly to the sea on either side and at its eastern end. At its western end, the ridge merges with an area of hilly country of general elevation 600 feet, and finally terminates in a lowland plain in the extreme western part of the Island. These topographical regions coincide with areas having different geological structure and composition. Thus, the main highlands consist of quartzose and micaceous schists outcropping on the N.E. side of the main divide, and of metamorphosed intrusive igneous rock (augite-andesite and diorite), outcropping on the S.W. side, and occupying about one-half of the total land area. Finally, the flat plain forming the westerly lands-end district, is made up of Tertiary and Post Tertiary geological deposits, consisting chiefly of a sheet of coral limestone recently raised above sea level.

(I) Highland Region.

This really forms a north-easterly extension of the Northern Range of Trinidad. The features of the schistose part of the Tobago highlands closely resemble those of North Trinidad, except that the Tobago schists are less quartzose, softer, and more deeply weathered. The igneous part of the highlands, however, has no parallel in Trinidad, except a small patch of andesite which outcrops near the north-eastern point at Sans Souci.

(*a*) *The Schistose Area*:—This area includes practically all the present Main Ridge Forest Reserve, and only a relatively small part of it has been cleared for agriculture. The cultivated part includes several cacao estates occupying the extreme north-eastern promontory of Tobago, around Charlotteville. Here the extent of soil erosion is not known, but it is probably small.

At the other end of the schist outcrop, within hilly country near the north-central coast around Parlatuvier and Castara, soil erosion is proceeding rapidly, particularly on the higher ground near the Main Ridge Forest Reserve from Pepper Village to Mt. Dillon, where land-slips of considerable dimensions frequently occur. The land is mainly tenanted by peasants who grow mostly provision crops on steep slopes which they have ridged along the contours, as shown in the accompanying photographs. During heavy rains, the contour ridges or banks frequently break down through pressure of water behind them, spilling the water onto those below, thus starting gullies whose dimensions increase rapidly.

The schist soil is, typically, a deep, friable, heavy sandy-clay, bright orange-red to red-brown in colour below the sparsely-humic surface soil. Although some attempt is evidently being made to combat soil erosion on these steep slopes, the methods at present in vogue would appear to be capable of further development. For example, greater provision might be made for removing water from the banks by opening slightly-graded contour trenches leading to the nearest gully or a carefully-prepared outlet, so that water-logging and the accumulation of water behind the banks might be prevented or reduced. These trenches may silt up periodically, but the silt may be spread onto the land so as to avoid loss.

(*b*) *The Igneous Area*: This includes the main bulk of the present-day cacao estates which occupy the broad ridges and valley flats forming the windward coastal belt which rises from sea-level to altitudes up to about 1,000 feet. Further west, the hilly lands around Mason Hall and extending to leeward are mainly under peasants' cultivations.

The whole of this igneous area has experienced an interesting agricultural history, which dates from the time when the Island was ceded to the British in 1763*. The first crop to be cultivated was sugar cane, and although cotton, and to a certain extent indigo, replaced it for a short period, sugar-cane was almost exclusively grown between 1795 and 1900, when the area of land remaining under this crop had diminished to less than 2,000 acres. During the one-hundred years' sugar era, all the land on the lower slopes of the igneous-rock area had been cleared of forest and laid out in cane-beds with little provision for conserving the rich humic soil. The use of the hoe, involving the general down-hill dragging of the soil, doubtless greatly accelerated erosion, and a considerable loss of soil must have occurred.†

Cacao has been grown on an appreciable scale in Tobago only since 1895, but the present-day cultivations date mainly from 1915 to 1920. Thus, the majority of the cacao trees now growing in Tobago were actually planted on land cleared from long-standing second-growth forest following the abandonment of the sugar-cane estates, though a small part may have been directly planted on land under sugar cane as recently as 1920.

* Tobago was first settled by the Dutch in 1628, but changed hands several times before it was ceded to Great Britain in 1763. Later it was ceded to France, retaken by the British in 1793, restored to France in 1802, and finally annexed to the British Empire in 1814.

† According to Mr. F. D. Davies, lately Agricultural Adviser in Tobago, the effect of long-continued sugar-cane growing in bringing about greatly accelerated soil erosion in the hilly lands of the Igneous Area, might equally well apply also to much of the Schistose Area; thus he states that remnants of a sugar factory occur at Bloody Bay where the river, once navigable to sugar barges for ¼ mile upstream, is now almost completely silted up. Also, at Englishman's Bay, masonry, marking the site of a sugar factory, is completely covered over with silt, and cacao trees are now growing on it. By way of contrast, at Hermitage, on the eastern side of Bloody Bay Hill, the walls of an old sugar factory are still well exposed, implying that erosion has not been so severe in this easterly part of the Schistose Area.

The fact that most of the cacao lands had previously been subjected to continuous soil erosion over a long period of time bears a peculiar and important relation to the depth and composition of the cacao soils of Tobago.* The characteristic soil profile developed normally over igneous rock in Tobago, under an annual rainfall ranging from 75 to 100 inches, as seen in the middle of the Main Ridge Forest Reserve, shows a sepia to chocolate-brown, crumby, fine-cloddy soil up to 15 inches deep, merging through a golden-yellow clay into whitish, greyish-green or brown rotten rock (parent soil material) at a depth varying from 3 to 4 feet. The rotten rock may be gritty and specked with blackish undecomposed augite crystals ("pepper-and-salt" appearance), or soft and uniform with the fine structure of chalk. The unaltered hard rock occurs generally only at very great depths, usually over 20 feet, though boulders and kernels, showing different degrees of weathering, may be interspersed within the rotten mass.†

It is seldom that soil profiles as deep as this are seen in cacao fields within the igneous part of Tobago.‡ Most that were examined during our reconnaissance soil-survey in 1930 were evidently deeply truncated, having lost much of their surface material, presumably through erosion. Indeed, in many cases, the existing soil would be classified as a *Lithosol*, in which erosion has outstripped soil formation.

Further evidence of this was provided by mineralogical examination of the sand fractions. The average content of coarse and fine sand in the *solum* is about 42 per cent., and 53 per cent. in the rotten rock (C-horizon). The sand grains consist for the most part of fresh, unaltered primary minerals (felspar, augite, olivine, magnetite).* Evidently the parent material of these cacao soils is only slightly weathered, and in this respect, it differs greatly from that of other examples of igneous rock soils occurring in the humid areas of the Caribbean Region whose parent materials consist simply of kaolinic clay, stained red by oxides of iron, and quite devoid of fresh primary minerals, such as comprised the original parent rocks.

In these more mature examples, a highly acidic base-deficient "*dead layer*" immediately underlies the humic horizon, thus interposing a thick inert barrier to penetrating plant-roots in search of mineral nutrients. This seriously limits the "feeding ground" of crop plants, particularly deep-rooted trees which perforce must obtain most of their nutrients from a relatively shallow surface layer of humic soil.†

The case of the present-day igneous rock cacao soils of Tobago is therefore unique in that it provides an example of a beneficial effect of deep erosion. Evidently the removal of a considerable amount of old surface soil and leached subsoil (the "dead layer") had exposed a mineral-rich parent soil material (rotten rock), from which a new soil was regenerated during the period when the hilly lands, formerly under sugar cane, had reverted to second growth forest. The benefit has been achieved, however, only at the expense of a long period of diminishing crop returns as the sugar-cane lands became less and less productive.

Much of the eroded soil has collected in the valley flats, so that the alluvial soils of the igneous area of Tobago are now the most productive of its present-day cacao soils; indeed they regularly give the highest yields of any cacao soils within the Trinidad-Tobago Colony. The alluvium is "living" alluvium, in that it is constantly receiving small deposits of surface soil from the slopes‡; the depth of humic penetration is much greater than that shown by sedentary soils derived directly from igneous rock.

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* *See* Cacao Soils of Tobago. (Part (III) of Studies in West Indian Soils); F. Hardy, C. G. Akhurst and G. Griffith, I.C.T.A., 1931.

† *Note*:—Red "lateritic" decomposition products rarely occur in Tobago, even in the highlands where the annual rainfall probably lies between 100 and 150 inches. This fact may be attributed partly to the extraordinarily free under-drainage, dependant on the occurrence of innumerable cracks, fissures and joints in the parent rock, resulting from its shattering by dynamo-metamorphism through profound earth-movements. Thus, water does not lie for a sufficiently long time in contact with the surface of the rock to effect the intense hydrolysis involved in laterisation.

‡ *Description of a typical cacao soil profile developed over igneous rock*: The average depth of the *solum* for 10 different profiles, reckoned to the level where rotten rock appears, is 30 inches (range, 15 to 46 ins.) as compared with 42 inches (range, 36 to 48 inches), for undisturbed forest soil profiles. The average thickness of the A-horizon is 8 ins., and of the B1-horizon to the full depth of humic penetration, 14 inches, leaving 8 inches for the non-humic B2-horizon.

The reaction of the humic soil is only slightly acidic (pH 6.6), but that of the B2-and C-horizons is increasingly alkaline (pH 7.1 to pH 7.7) within the rotten rock zone, indicating very little leaching within the profile, and proving the absence of a "dead layer."

The average organic matter content is 1.8 per cent., with 4.2 per cent. concentrated in the surface 6-ins. layer. Carbon-nitrogen ratio averages 10.1 in the surface 6-in. layer, and diminishes rapidly below.

* According to Vageler (*Tropical Soils*, 1933, London), these values denote a soil having very high "permanence of fertility". For sandy soils, the lower limit of fresh mineral content is set at 15 per cent. by weight for high fertility in tropical soils.

† *See*: Some Aspects of Cacao Soil Fertility in Trinidad; F. Hardy, *Trop. Agriculture*, 1936, XIII pp. 315-317.

‡ In support of this statement, Mr. F. D. Davies, lately Agricultural Adviser in Tobago, provides the information that a number of 4-inch earthenware tile drains was found at a depth of 8 feet in the Roxborough Flat when a drainage canal was being cut. It is unlikely that these pipes were originally placed at a depth greater than 4 feet, so that a 4-foot layer of eroded soil has probably been deposited as alluvium since the slopes around the flat have been subjected to accelerated erosion through sugar-cane cultivation.

(II) Lowland Region.

The south-western coralline plain of Tobago, 10 square miles in area, is bounded by the sea on three sides. The land rises in flat terraces up to about 120 feet altitude, and ends seawards in cliffs 15 or 20 feet high. It is covered mostly by a chocolate-red clay soil of variable thickness, presumably derived directly from the weathering products of the coral limestone. The soil is a shallow *Terra Rossa* type; it is free-draining and exhibits a marked crumb structure. It has probably been long exposed to sheet erosion, owing to the fact that much of the land has been growing coconuts for many years, or has been under peasants' garden cultivations or in pasture.

Soil Conservation in Trinidad-Tobago.

In common with other British West Indies islands, no general policy for combating soil erosion and conserving the soil, other than demarcating certain areas as permanent forest reserves, has yet been formulated and put into general practice in Trinidad and Tobago. Indeed even the first stages of such a policy, namely the education of agriculturists, both estate owners and peasants, into the causes, indications and methods of control of soil erosion, have not yet been initiated by means of posters, pamphlets, lectures and demonstrations, with the sole exception of a leaflet issued in 1936 by the Lands Advisory Committee on deforestation in the Northern Range, and another one on the lay-out of peasants' gardens.* There are signs, however, that administrators and planters are at last beginning to realise the significance of soil-erosion, and that "erosion-consciousness" and "soil-mindedness" are being aroused, partly through the influence of the many excellent publications emanating from the Soil Conservation Service of the United States of America.

The officers of the Government Forest Department of Trinidad and Tobago are fully aware of the dangers that are attendant on indiscriminate forest felling, and their forest policies aim at conserving the soil and preventing damage to lands already under productive agriculture. The general situation with regard to forest reservation for regulating the Colony's water-supply is regarded by the Conservator of Forest as satisfactory, except that the lands of the western part of the Northern Range give cause for anxiety. Until 1932, this area was mainly under privately-owned cacao or in forest or second growth bush, but, since the onset of the cacao depression, land owners have been renting out steep hillside lands to peasants for growing food crops. The peasants prefer to cultivate the highest and steepest parts of the hills so as to reduce the chances of loss by praedial larceny. The practice of shifting cultivation put into effect in these places has initiated soil erosion, land-slip and flooding on an increasing scale, particularly since the demand for land on which to grow more food has increased since the War began.

A full report on the position, and remedial measures for erosion control have been submitted to Government by the Lands Advisory Committee, and it is hoped that active steps may soon be taken to bring relief. In his article on deforestation in the Foothill Belt of the Northern Range, J. C. Cater, Assistant Conservator, suggests two methods for controlling soil erosion. The first, more drastic, method is to prohibit shifting cultivation on slopes above the 300 feet contour, and to allow the land to revert to forest. This would involve the alienation of several thousands of acres of peasants' land at present utilised for growing provision crops, and to compensate for their loss, it is recommended that a similar acreage of abandoned or unprofitable cacao land, or derelict waste-land on the flats, be converted into mixed vegetable and animal farms for the accommodation of the displaced peasants.

The second method advocated by Cater is to prohibit cultivation above a higher altitude, say the 500-feet contour, and to introduce soil conservation methods such as terracing, contour ridging and contour strip planting of binding grasses on the lower slopes. Between the 500-feet and the 800-feet contours, the planting of permanent tree-crops such as Limes or Tonka Beans, might be permitted, provided the ground is suitably grassed down, but above 800-feet, the land should be allowed to revert to forest, though cacao cultivations might be permitted where feasible.

During the year following the outbreak of war, the Department of Agriculture laid down a few model school gardens, involving demonstrations of soil erosion control for the purpose of educating children, but unfortunately the plan was not developed, nor has the number of demonstrations been further multiplied.

During the laying out of hillside gardens in general, attention should be given to their shape, orientation, separation and arrangement. The best shape is a narrow rectangular strip running parallel to the contours. Ideally, adjacent gardens should invariably be separated by strips of uncultivated land on all sides, but this protection may be hard to attain in practice, since the setting out, planting and maintenance of the separating strips may be difficult to accomplish as well as costly. Peasants' gardens should be arranged *en échelon* and not directly one below the other. Water-courses and ravines should be avoided; they should never be included within a garden, but left uncleared in bush, or planted in some suitable binding creeper or deep-rooted shrubby plant species.

* Another exception might be cited in the publication in March, 1921, by the Agricultural Society of Trinidad and Tobago, of a leaflet entitled "Contour Drains or Canals on Hillsides", compiled by F. D. Davies, then Agricultural Adviser in Tobago (Society Paper, No. 759), in which the downhill system of drainage, at that time in vogue in certain parts of Tobago, was condemned, and the construction of contour trenches strongly advocated.

Fire control is imperative in areas where peasants' gardens have been laid out. The setting of fire to bush should be avoided wherever possible, but if fire must be resorted to for the purpose of clearing land in fallow prior to cultivating it, the regulations regarding the provision of suitable fire traces should be strictly observed. Owners of land who let garden lands to peasants are urged to ensure that these regulations are fully complied with. Burning should only be carried out when there is no breeze blowing that is, early in the morning or late in the evening in Trinidad. The peasant himself should be present during the burning, and should not leave his garden until the process is completed and all traces of fire have been extinguished. Failure to observe these precautions, and lack of adequate supervision during burning, have been a frequent cause of the uncontrollable spread of many destructive fires during recent years, especially in the Northern Range Foothills of Trinidad.

Summary.

Soil erosion in Trinidad and Tobago is mainly insidious sheet-erosion, which is variably affecting both sloping ground and flat alluvial lands. In addition, clay soils within wet areas are subject to land-creep and land-slip movements (namely, soil-creep, earthflow and débris-avalanche ; slump, débris-slide and débris-fall).

Erosion in Trinidad and Tobago is described in this article for each of the main topographical divisions in turn.

(A) Trinidad.

(1) *In the Northern Range,* unrestrained deforestation and agricultural exploitation by peasants, particularly in the Foothill Belt of the western part of the Range near Port-of-Spain, are serious and menacing. As a result of shifting cultivation, extensive sheet erosion and gully erosion have caused considerable soil wastage, and have encouraged flooding on the lower grounds during rainy seasons.

(2) In the *Northern Plain,* the effects of erosion are not spectacular, though every flooding rainstorm exacts its toll of surface soil from the cacao estates of the Sangre Grande Basin, as well as from exposed peasants' holdings in the hilly Las Lomas District, and from the high-cambered beds of long-cultivated cane-fields in the sugar estates of the Caroni Plain. The water courses of the Oropuche and the Caroni drainage systems are silt-laden throughout the wet season, and mud barriers are forming outside their estuaries.

(3) In the *Central Range,* sheet erosion is affecting cacao lands, but the most spectacular forms of erosion, both within the forest and in the cultivations, are land-creep and land-slip movements, which displace trees as well as obstruct roads within the areas where gypseous clays outcrop.

(4) In the hilly sugar-cane lands of the western part of the Naparima Clay Belt, *Southern Plain,* soil erosion is enhanced by ploughing with heavy tractor-drawn implements that turn the soil downslope, exposing grey marly subsoil or red gypseous clay because of profile truncation on the crests. The forest and cacao lands comprising the eastern and southern parts of the undulating plain show sheet erosion, though its effects are here difficult to assess.

(5) The *Southern Range* and (6) the *Cedros Peninsula* are mostly under forest ; the loose sandy soil which covers their greater part erodes rapidly when exposed by tree felling and burning.

(B) Tobago.

Erosion in Tobago at present is important chiefly in the Castara and Mason Hall Districts whose soils are derived from soft schists (comparable with the metamorphic rocks of the Northern Range of Trinidad), or from igneous rocks (andesites mainly) that are prone to erosion because of the steeply-sloping topography.

Within the *Windward Cacao Belt* of Tobago intensive erosion during the century-long era, of intensive sugar-cane growing has effected considerable profile truncation in the hilly igneous rock soils that had originally developed under forest. In many cases, the rotting igneous rock was exposed, and from this parent material new soil developed during the period when the land had reverted to second growth bush before being brought into cacao cultivation. Hence the present-day cacao soils are mostly immature or rejuvenated, and might best be described as Lithosols.

Soil conservation in Trinidad and Tobago has not yet been systematically practised, nor has adequate publicity been afforded to it by competent authority. The co-operation of planters and land-owners is essential in any attempt to stop further depredation.

Acknowledgment.

The writer's thanks are due to R. L. Brooks, Esq., Conservator of Forests, and to J. B. Hutchinson, Esq., temporary Erosion Control Officer, Department of Agriculture ; Geneticist E.C.G.C., Cotton Research Station, for kindly furnishing notes on soil conservation from which the last section was mainly compiled. The writer is also indebted to the Acting Director of Agriculture (R. O. Williams, Esq.) and to members of his staff (P. E. Turner, Esq., Dr. F. J. Pound, F. D. Davies, Esq. and A. P. McWilliam, Esq.) for kindly reading the manuscript of the article.

FIELD EXPERIMENTS ON SUGAR CANE IN TRINIDAD.

Annual Report* for 1941 by P. E. Turner, Sugar Agronomist to Department of Agriculture and Sugar-Cane Investigation Committee of Trinidad.

This Report, which comprises 196 pages, follows the main lines of the corresponding Reports for 1939 and 1940.† It is divided into nine sections—(1) Ground limestone, (2) Sulphate of ammonia, (3) Potash, (4) Phosphate, (5) Auxiliary elements, (6) By-products as manures, (7) Cultural methods, (8) Planting methods and (9) Varieties. In each section the effects of the various treatments on yield of cane, on quality of crop and on yield of sugar are fully considered. Data for the experiments reaped in 1940 and in earlier years are recorded provided that these experiments were reaped again in 1941.

The experiments which are described fall into three types—(*a*) experiments with a large number of treatments and complex layouts to obtain fundamental information, (*b*) experiments with few treatments, a large number of replicates and simple Latin-square layouts, to enable quantitative recommendations as to optimum economic size of dressing and number of applications of manures, most appropriate cultural and planting methods, most suitable variety of cane, etc., and (*c*) permanent experiments to measure the effects of standard manurial dressings continued over a long period of years with special reference to the relative merits of organic and inorganic manures. At the end of the Report the general conclusions to which these experiments give rise are summarised with special reference to soil type. In view of the information of both scientific and practical value which it contains the Report is worthy of detailed study.

The Report presents an excellent example of the progress which can be made through the co-operation of the scientist and the planter. All the experiments were laid down on sugar plantations. With the aid of the field officers of the plantations and the chemists of the factories, a limited research and controlling organisation has been able to develop the scheme of experiments on a very large scale, to work on a number of different problems simultaneously, to examine specific problems on widely differing soil types at the same time, and to maintain a very high standard of accuracy throughout.

From the early years of the scheme (which was begun in 1927 with a single manurial experiment) the yield data given by the field experiments have been linked with chemical analyses of the soils of the experimental areas. By these means it has been found possible to make quantitative recommendations of assured value as to the manuring of sugar cane with lime and potash based on soil analyses. Members of the staffs of sugar companies have been trained in the appropriate analytical technique in the laboratories of the Sugar Agronomist and the companies themselves have then undertaken the detailed field-to-field soil surveys of their plantations with respect to lime and potash requirements. Large areas have been covered and the manurial programmes of these areas have been based on the data accumulated. Progress has also been made by the Sugar Agronomist in linking the yield data given by the field experiments on phosphatic manures with available soil phosphate.

There are four appendices to the Report—(1) Output of cane and sugar (1928-40), (2) Imports of inorganic manures (1928-40), (3) Proportional distribution of sugar-cane varieties reaped on estates (1935-41), and (4) Rainfall (1935-41). The output of sugar in Trinidad increased from an average of 75,374 tons a year for the five years 1926-30 to 132,671 tons a year for the five years 1936-40. Coupled with this expansion in output is a tremendous increase in the use of inorganic manures. As a direct consequence of the results of the field experiments the amount of sulphate of ammonia used increased from 600 tons in 1928 to an average of 7,573 tons a year for the five years 1936-40. Figures for ground limestone are not quoted by the author but they are known to show an equally remarkable increase. There has also been more extensive use of potash. In 1928 the manurial treatment of sugar cane in Trinidad was based almost entirely on pen manure. As a result of the field experiments it is now mainly based on inorganic manures.

Particular attention is being paid to varieties of cane in the experimental scheme. The varietal investigations have followed three main lines—(*a*) attempts to increase the proportion of the total area under sugar cane suited to the growing of noble varieties by improvements in agricultural methods, (*b*) comparisons of varieties recently imported from Barbados and elsewhere with the standard varieties, and (*c*) a detailed field-to-field soil survey with particular reference to the allocation of varieties. Between 1935 and 1940 the proportion of the total area under noble canes (B.H. 10(12) and B. 726) increased from 54 to 61 per cent., whilst that under hardy canes (Uba and Co. 213) correspondingly decreased. The change has been in the main due to greater realisation of the importance of thorough drainage and to improvements in manurial and cultural methods based on the results of field experiments. The comparisons of varieties recently imported with those in standard use indicate that important changes in the varietal situation are impending.

* Copies of this Report may be obtained on application to the Sugar Agronomist, Sugar-Cane Investigation Committee, Department of Agriculture, St. Clair, Trinidad, B.W.I.

† *Tropical Agriculture*, 1940, Vol. XVII, No. 2, pp. 25-26; 1941, Vol. XVIII, No. 7, pp. 141-142.

For example the Puerto Rican variety P.R. 803 (which has the merit of being resistant to froghopper damage) has been found to give larger yields of plant and ratoon cane and sugar on an area of high fertility, whilst the varieties B. 34104 (which is susceptible to froghopper damage) and B. 3439 from Barbados have been shown to give great promise of replacing Uba and Co. 213 on large areas of soils of intermediate and low fertility.

The detailed field-to-field soil survey with special reference to the allocation of varieties is being undertaken by Mr. C. F. Charter. A brief description of the soil types of the sugar-cane areas, and a grouping of these types with respect to moisture relationships, by this worker is included in the Annual Report of the Sugar Agronomist. In the same way that it has been possible to make quantitative manurial recommendations on a field-to-field basis by linking the results of the manurial experiments with chemical analyses of the soil, so in due course it will be possible to make specific varietal recommendations on a field-to-field basis by linking the varietal experiments with the soil survey.

PHOSPHATE FIXATION IN SOILS.*

When phosphates are applied to soils they readily change to less soluble forms, the availability of which varies greatly, depending upon the degree of fixation. It is difficult to distinguish between fixation by adsorption and fixation by chemical precipitation, especially in view of the results obtained in recent researches in which it has been shown that the crystal structure of kaolinite is changed to a new crystal structure after fixing phosphate. This effect would seem to indicate that chemical precipitation has occurred, but since it is reported that the phosphate-ions are exchanged for hydroxyl-ions of the kaolinite, it would indicate a type of adsorption.

Most of the contributors who support the theory of phosphate fixation by adsorption have attempted to show that the fixed phosphate occurs in an exchangeable form, and that it may readily be replaced by other ions. A number of workers have shown that the hydroxyl-ion is quite effective in replacing or liberating adsorbed phosphate, but in certain instances, it is likely that the fixing complex is partly dissolved, because of the increased alkalinity. Citrate-ion has been used and found to be advantageous in this respect, but its effect also may be due to its dissolving power, since citric acid quite readily dissolves iron phosphate. Oxalate-ion has also been proved to reduce phosphate retention, but oxalate apparently removes only small amounts of phosphate, and there is no indication of an equivalent replacement. Silicate-ion has also been reported as capable of replacing phosphate, and this fact has been suggested in explanation of the increase in available phosphate content of soils and for the favourable effects on crop-growth which occur when sodium silicate is applied to some phosphate-deficient soils. The existing evidence, however, indicates that the silicate may dissolve rather than actually replace the native phosphate in soils.

Until recently, a number of workers have inferred that soluble iron and aluminium compounds in acidic soils are the main agents which render phosphate only slowly soluble and not readily available to plants. While this may be the case, it does not seem probable that fixation by iron and aluminium is solely responsible because free iron- and aluminium-ions are not present in the soil solution to any appreciable extent, except in very acidic or highly alkaline soils. Furthermore, a number of investigators have shown that freshly-precipitated iron and aluminium phosphates are quite readily available to plants. On the other hand, certain phosphates of iron and aluminium are known to be only slightly soluble and only slowly available. These phosphates may perhaps be formed in soils by interaction between soluble phosphates and hydrated oxides of iron and aluminium, even though these may not occur in true solution. It seems likely that phosphate forms complex addition compounds with hydrated iron and aluminium oxides, because the speed at which fixation take places precludes the possibility of a gradual solution of iron and aluminium and their re-precipitation as phosphates. Certain hydrated iron oxides seem to reduce phosphate availability more than iron hydroxide.

Practically all acidic soils contain considerable amounts of hydrated iron oxide, and since it is distributed as thin films over the soil particles, it is in an ideal condition for reacting quickly with soluble phosphate. Aluminium oxide seems to be of lesser importance, because it is usually present in smaller amounts. Fixation by hydrated iron oxides on the surface of soil particles may be of considerable importance, especially in lateritic and podsolized soils. The addition of lime to acidic soils seems to reduce this type of fixation, not because it lessens the activity or the amount of the hydrated iron oxide present, but mainly because of the low solubility of the calcium phosphates which are formed, since both di- and tri-calcium phosphates exhibit low water-solubilities.

Low availability of phosphate in alkaline calcareous soils seems to be due to its occurrence as a carbonate-phosphate complex rather than

* Abridged from the summary of a review article on this subject by A. R. Midgley, of the University of Vermont, U.S.A., which was published in the *Proceedings of the Soil Science Society of America, for* 1940 Vol. 5, 1941, pp. 24-30.

tri-calcium phosphate. Fluoro-phosphate or fluor-apatite may also be formed under such conditions, because fluorine frequently occurs in the underground waters of calcareous soils, and it readily reacts with tri-calcium phosphate under alkaline conditions to form fluoro-phosphate. Since superphosphate also often contains active fluorine, care should be exercised in using it for improving alkaline soils, because fluoro-phosphate may be produced in the soil. While this compound is slowly soluble, its availability to plants in alkaline soils has not been demonstrated.

SOIL STRUCTURE.*

Although a general knowledge of and an interest in soil structure have occupied a definite place in the advancement of soil science, there has been a renewed interest in the practical application of soil physics within recent years. This is due partly to a clearer understanding of what constitutes structure and structural stability and to a recognition of the great importance that permeability plays in water absorption, run off and erosion, and possibly soil respiration. It has been shown that the soil mantle is a tremendous reservoir for water and that any reasonable precipitation can be accommodated by almost any soil, provided such precipitation can enter as fast as it occurs. It can also be shown that among cultivated soils, in the majority of instances the first few centimeters of the exposed surface is the least absorptive layer. Virgin forested or grassland soils normally possess a good structure and permeability in the upper horizons.

Soils brought under cultivation, particularly if the cropping systems are such that the surface is not covered for a considerable proportion of the time, are gradually subjected to forces which tend to break down those natural structural aggregates which may have persisted for centuries under natural conditions.

Among the structure- and permeability-destroying forces which operate upon soils under cultivation, the following may be mentioned: impact of beating rain drops upon exposed aggregates; shearing, polishing action of plough shares and other implements; leaching of soluble salts from upper layers during long fallow periods, resulting in dispersion of aggregates surrounded with a solution of low osmotic concentration; absence for long periods, at or near the surface, of organic residues to serve as food for macro and micro life; destruction of vertical channels by horizontal tillage operations; compaction resulting from animals, man, or machine. These and many other forces are permitted to operate in and on soils under cultivation but are virtually non-existent in soils under natural forest or grassland conditions.

It seems desirable, therefore, that cultural practices, rotations, and cropping systems be examined with a view to determining whether, and to what degree, each system or practice tends to destroy or repair structure. Doubtless much of the phenomenon known as soil depletion may be explained as directly or indirectly due to destruction of permeability. It is recognized that a long time may be required to produce any permanent alteration in the aggregate condition of a soil; hence it seems desirable to study present conditions in soils the history or treatment of which is known, rather than to set up an experiment designed to determine such structural changes which might not produce significant alterations for a quarter to a half century.

This paper deals with the examination of different methods for measuring structural stability and the adoption of a satisfactory procedure, and the application of this procedure in the study of experimental plot soils which have been under known treatment and cropping plans for many years.

The physical condition which determines infiltration and percolation rate is related to total pore space, size of pore, non-capillary porosity, volume weight, swelling capacity, dispersion ratio, and state of aggregation. Immediately following any tillage operation a soil may appear to be in good tilth. But how persistent is this condition? Is it destroyed by one or two rains, or does the soil retain its absorptive capacity even after several rains? If its granules are of sufficient size and stability, it will retain its absorptive capacity, but if they are readily dispersed, surface run off will take place.

A method is described which is sufficiently refined to reveal the small alterations in aggregate size and stability that may be produced within a single soil type by different soil treatments through variations in cultural practice, fertilization, erosion, &c. A numerical measure of the structural stability of the aggregates and the probable permeability of soils is presented.

When the method is used to study differences in structure and permeability produced by cropping systems, fertilizing, and liming, it was shown that on a single soil:

(*a*) A rotation of corn, oats, wheat and clover over a period of 58 years caused a breakdown of aggregates as compared with sod land adjacent.

(*b*) A vegetable cropping system including no sod crop, and with cover crops only for soil improvement, produced after 21 years a poorer structural condition than the rotation described in (*a*).

(*c*) Farm manure whenever used produced definite physical improvement.

(*d*) Liming did not significantly alter the structural condition.

* Notes copied from: "The measurement of structural stability and permeability and the influence of soil treatments upon these properties." R. B. Alderfer and F. G. Merkle. *Soil Science*, 1941, Vol. 51, pp. 201-212, 1941.

(*e*) Other things being equal, structural stability is closely correlated with the organic content.

(*f*) The volume weight exhibits a significant inverse relationship with structural stability, probably permeability, and organic content.

REVIEW.

VEGETABLE GARDENING IN MALAYA.

By J. N. Milsum and D. H. Grist, Malayan Planting Manual, No. 3, published by Department of Agriculture, Straits Settlements and Federated Malay States, Kuala Lumpur, 1941, pp. xviii +206, price $2.00 (4*s*. 8*d*.).

As an introduction to this review on "Vegetable Gardening in Malaya" the following explanatory passages are quoted from the Preface written by the Director of Agriculture, Straits Settlements, and Adviser of Agriculture, Malay States. "This is the third special publication of the Department of Agriculture Straits Settlements and Federated Malay States dealing with the subject of vegetable culture in Malaya. . . . In view of the present demand for a book of this description and of the obvious desirability for increasing the production of vegetables in this country the whole question of vegetable production has been brought under review and is presented to the public in the present volume . . . .

. . . The authors have drawn information from the previous two publications on this subject, but the book has been entirely recast and re-written and will be found to contain much information additional to that set forth in its predecessors."

The need and demand for a publication of this description are by no means restricted to Malaya and in view of the equally obvious desirability for increasing the production of vegetables in other parts of the Colonial Empire the appearance of this book is most opportune. It furnishes a very comprehensive account of vegetable culture in a range of tropical conditions and no important aspect of the subject fails to receive detailed consideration.

In general, the first six chapters deal with principles and methods of vegetable culture. Chapters eight to thirteen contain descriptive accounts of vegetables of all types and classes, suitable methods of propagating and cultivating them, and the uses which can be made of them. Chapter XIV is devoted to a discussion of organized vegetable production. Chapter XV gives a very useful and handy account of the food values of vegetables and their relative importance in the diet. Chapters XVI and XVII describe the common insect pests and diseases of vegetables in Malaya and the methods recommended for their control.

Referring to a few points in greater detail, the authors ensure that the prospective gardener shall make a good start by describing in Chapter II certain fundamental aspects of vegetable culture, such as the selection of the site for the garden, the objects and methods of tillage, and the need for drainage and soil conservation measures. The vital importance of an adequate supply of organic matter in the soil is stressed and the statement that few Malayan soils are well supplied with organic manure is equally applicable to many soils in other parts of the tropics. Hence Chapter III on manuring deserves special study. In this Chapter organic and artificial manures are described and attention is drawn to the possibility of wasting manure by incorrect applications. Prospective gardeners should take the precaution of having their mixtures of artificial fertilizers prepared in accordance with their local soil requirements and should avoid the mistake of blindly applying mixtures because they have proved to be successful in other countries where conditions might be entirely different. A valuable discussion on the preparation and use of compost is given in the Chapter on manuring, but the procedure described is perhaps unnecessarily elaborate; simpler methods are described* and practised elsewhere and gardeners should consult their local agricultural departments as to the simplest method suited to their conditions and circumstances.

In Chapters IV and V the lay-out of a small garden, routine practices and a system of crop rotations are described. Here again gardeners should not blindly adopt rotation systems intended for other countries but should seek advice from their local agricultural department.

A special chapter has been devoted to a description of Chinese market gardening as practised in Malaya. The main point worth noting about Chinese market gardening is that it differs in no important respect from any other form of gardening, but the Chinese gardener is successful because he puts industry and hard work into the job and consequently his crops do not suffer from neglect. The fact that he takes unattractive "land" and converts it into productive "soil" by skilful methods and adequate attention deserves careful consideration by other types of gardeners.

In "Vegetable Gardening in Malaya" the authors have furnished tropical agriculturists with a very helpful and complete guide to gardening whether it be on the larger scale of several acres or on a small area of a few score square feet adjacent to a house. Every class of vegetable gardener and all authorities responsible for the teaching of vegetable gardening are strongly recommended to study the book.

The book is well printed and contains a large number of illustrations of vegetables. Copies are obtainable from The Malayan Information Agency, 57, Trafalgar Square, London, W.C.2, or the Department of Agriculture, Kuala Lumpur, Federated Malay States, at a cost of 4*s*. 8*d*. each.

**Emp. Jour. of Exptl. Agric.*, VI., 24, Nov. 1938.

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Potash Deficiency in Tea Cultivation.

Dr. Eden in a paper in the *Tea Quarterly* 13: 146-7, gives some results obtained from potash experiments, still in progress. These bear out certain Dutch results so far as the conditions are comparable, namely, stated generally, that the potash content of the tea leaf is susceptible to modification within wide limits by the amount of potash available in the soil. A beneficial effect from adding potash fertilizers may be expected on soils containing up to .017 per cent. of potash. On soils increasingly rich in available potash this effect is rapidly diminished. The plant, it is suggested, can however accumulate potash in amounts appreciably in excess of its maximum requirements for growth and crop production. In Java potash deficiency reduces the prunings by more than 50 per cent., but in Ceylon the difference is only 2.5 per cent. In Ceylon 9 years' cessation of manuring with potash has diminished yield neither of flush nor of wood nor, over a 6-year period, has it reduced the foliar diagnosis figure to the deficiency level.—(*Horticultural Abstracts*, XI, No. 3, 1941.)

* * *

Mineral Composition of Sugar-Cane Varieties and possible relationship with their Mineral Nutrition.

One of the modern developments in the study of the mineral nutrition (use of fertilizers) of crops is the use of "foliar diagnosis" for ascertaining whether the soil of a cane field has enough of the common plant nutrients to make a satisfactory crop. The procedure is to take samples of the leaves of young plants, and by simple and rapid chemical tests to determine how much nitrogen, phosphate, and potash they contain. If the leaves show much phosphate and little potash it may be concluded that an application of potash fertilizer would be beneficial, while it would probably be of little use to apply phosphate. This procedure assumes that the mineral content of the plants will be in direct proportion to the mineral content of the soil. On this assumption has been founded what is known as the "index of nutrition" of plants. Thus, if analysis of the leaves show 2.49 per cent. of N, 1.10 per cent. of P_2O_5, and 3.72 per cent. of K_2O, the sum of these percentages is 7.31, which is taken as the index of nutrition of the plants. If the sum of these percentages is higher or lower, it is supposed that the plants will be better or worse nourished.

However, recent work by C. E. Beauchamp and J. E. Alvarino shows that this theory must be taken with reservations. They grew seven varieties of cane on the same soil, and analysed their leaves. The analyses showed that these seven varieties were clearly divisible into two groups. One of these groups had high percentages of N, P_2O_5, and K_2O, whereas the other group contained distinctly less of these elements. The former group therefore has a higher "index of nutrition" than the latter. Nevertheless, the apparently poorly-nourished varieties were those which gave the highest yields. Yielding ability is therefore inversely instead of directly proportional to the quantity of mineral constituents absorbed by the plants. The authors point out that this finding is in line with the agrobiologic principle known as the inverse-yield nitrogen law. This law states that yielding ability of crop plants is inversely proportional to the percentage of nitrogen in the normally-cultured plant. Plant varieties differ in the yields they will make from the same amounts of nitrogen and other nutrients absorbed by them; in other words, the high-yielding varieties make a little nitrogen "go farther," and thus appear to be less well nourished than sluggish varieties which have absorbed the same weight of nutrients but are not able to make good use of it. For this reason, the poorer varieties will contain a greater percentage of nutrients than the better ones. It therefore appears that the so-called index of nutrition must be reconsidered in the light of these facts.—(*Sugar*, 1941, pp. 77-78.)

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Mineral Composition of Entire Sugar-Cane Leaves and their Alcohol Extract as Indicators of Soil Fertility.

Pursuing his studies on the analysis of leaves of sugar cane as an index of the fertilizer needs of the soil, C. E. Beauchamp considers the relative value of an analysis of the whole leaf in comparison with extracting the leaves with alcohol and analysing the extract. It turns out that the alcohol dissolves a large proportion of the potash in the leaves, so that as regards this element the test can be made much more sensitive. Thus it was found that an application of no more than 16.6 lbs. of potash to the acre could be detected by an increase in the potash content of the leaves, whereas an application of 50 lbs. per acre was required for making a showing in a direct analysis of the whole leaf. On the other hand, alcohol dissolves very little of the nitrogen and phosphate from the leaf, so this method has not the same advantage as in the test for potash.—(*Sugar*, 1941, p. 78).

ERRATUM.

We regret that the following printer's error was made in Sir Arthur Hill's obituary notice which appeared in our last issue (January, 1942):—

Page 3, col. 2, under Obituaries, line 10. For "Writing in Trinidad, we omit" *read* "Writing in Trinidad, we cannot omit."